(12) UK Patent Application (19) GB (11) 2 096 819 A

(21) Application No 8208961
(22) Date of filing 26 Mar 1982
(30) Priority data
(31) 375110
(32) 9 Apr 1981
(33) Canada (CA)
(43) Application published
20 Oct 1982
(51) INT CL$^3$
H01B 11/02
(52) Domestic classification
H1A 1C 2E3D2 3G
(56) Documents cited
GB 1361356
GB 1268280
GB 1100819
US 3710006
(58) Field of search
H1A
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# (54) Electrical conductor for telecommunications cable

(57) Insulated electrical conductor for telecommunications cable in which two layers of insulation are provided. The inner 16 of the two layers is a solid non-cellular construction and the outer layer 17 is cellular. The nominal mutual capacitance between the conductor and an identical conductor is at a desired value with a dielectric breakdown value between conductors above a desired minimum value while having an outside diameter across the insulation which is less than for a conductor of the same gauge which provides the same mutual capacitance and has a solid insulation of the same material as the inner layer e.g. polyethylene or polypropylene. The cellular material may be a closed or open foam.



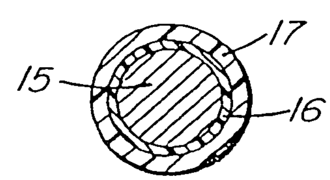


FIG. 2

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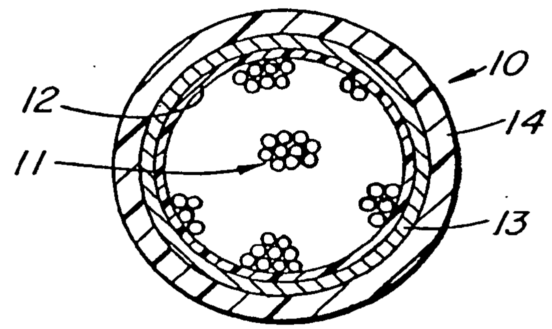


FIG. 1

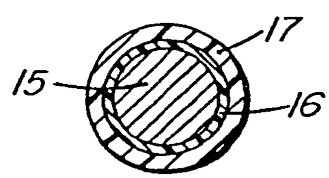


FIG. 2

SPECIFICATION
**Electrical conductor for telecommunications cable**

This invention relates to an insulated electrical conductor for telecommunications cable.

Telecommunications cables conventionally comprise a plurality of individually insulated conductors, usually twisted together in pairs, the conductors forming a core encased in a cable sheath. In "air core" polyolefin insulated cables, i.e. those not filled, the usual practice in some countries is to use an insulation consisting of solid non-cellular polymeric material.

Interstices exist between the insulated conductors. If perforations are present or are otherwise formed in the sheath e.g. due to lightning or mechanical damage, it is possible in certain applications for moisture entering into the cable to reach these interstices and to fill them for long distances along the cable by migration. The presence of this moisture degrades the electrical performance of the cable and may even cause short circuits between conductors when pinholes or other defects are present in the individual insulation of the conductors. The moisture acts as an electrolyte to lead to corrosion of exposed metal surfaces directly or by facilitating galvanic action.

In view of all these problems, for instance for buried cable, the interstices between conductors in cable cores have been filled with a water repellent and water impermeable medium such as grease or petrolatum jelly.

Known filling materials all have a permittivity greater than 1 which is the permittivity of air. Hence, displacement of the air from between the insulated conductors by these filling materials affects the electrical characteristics and thus telecommunication characteristics compared to air-core cable. For instance, where grease is used as filling material, these changes are in some respects deleterious in that the filling materials increase the capacitance between adjacent conductors, but it is also found that the grease advantageously increases the dielectric strength of the insulation.

Originally, the problem of increase in capacitance with grease filled cable was overcome by an increase in the thickness of the individual solid insolution on the conductors, but this resulted in an increase in the amount of insulation material required over that for air-core cable and hence an increase in cable diameter which, is undesirable for cost and installation reasons.

The above further problem of increase in the amount of insulation material and cable diameter has been overcome by an invention described in Canadian Patent No. 952,991. In this patent, there is described a communication cable having a filled core of a plurality of insulated conductors, the insulation on each conductor comprising an inner layer of cellular polymeric material and a relatively thin outer layer of solid polymeric material. The cellular polymeric material has the advantage that it has a lower permittivity than solid non-cellular materials and is adjacent to the conductor to retain the capacitance down to commercially acceptable levels. This also results in a saving in materials in replacing solid material with cellular material and the overall diameter of each insulated conductor is reduced, thereby advantageously reducing the outside cable diameter for filled cable. In an example given in the copending applications, the inner layer of cellular insulation, on 22AWG aluminum conductor, has a thickness of 9 mils with 40% of its volume being air, and the outer solid layer has a thickness of 2.5 mils, the overall diameter of the insulated conductor being approximately 48 mils. The dielectric strength between conductors is held at acceptable levels mainly by the combined dielectric properties of the outer solid layer and the surrounding filling material in the core.

Unfortunately, in this described construction, the dielectric strength between conductors would be lower and possibly may not be acceptable if this cable was air-core cable. In addition, it should be realised that these results would be obtained with an outside diameter of 48 mils for 22 AWG which is greater than a conventionally insulated conductor of less than 45 mils and which provides commercially acceptable levels of nominal capacitance and dielectric strength. However, it is extremely important that cable diameters should be as small as possible as the spaces for accepting cable are very restricted. Of course, cable diameter is governed by outside diameter of insulated conductor.

The present invention is concerned with the provision of an electrically insulated conductor for telecommunications cable which is useful for air-core and filled cable particularly when filled with particulate material and when included in air-core cable exhibits dielectric strength and capacitance properties which are within commercially acceptable levels while having a smaller outside diameter than comparable insulated conductors for air-core cable and which have a conventional solid insulation.

Accordingly, the present invention provides an insulated electrical conductor for telecommunications cable comprising a telecommunications conductor and an insulation comprising an inner layer and an outer layer of electrically insulating material, the inner layer of solid non-cellular construction and the outer layer of cellular polymeric material, and wherein the nominal mutual capacitance between the conductor and an identically insulated conductor in a pair is at a desired value and a dielectric breakdown value above an acceptable minimum is obtained between the conductor and an identically insulated conductor while having an outside diameter across the insulation which is less than an insulated electrical conductor of the same gauge which provides the same mutual capacitance and which is insulated with solid non-cellular material only, that material being the same

material as said inner layer. The inner layer may be pigmented but there should normally be no reason for this. In any case, avoidance of pigmentation provides the better dielectric strength.

The desired mutual capacitance is dependent upon requirements laid down by any particular authority. For instance, in some cases, a nominal mutual capacitance value of 83 nanofarads/mile is the requirement. This of course may vary between acceptable manufacturing limits, say between 79 and 87 nanofarads/mile.

From the above defined invention, it is clear that with the materials arranged in the layers as specified, the desired values of nominal mutual capacitance and of dielectric strength are achievable with an outside diameter across the insulation which is less than with a conductor having a single layer of insulation.

It is found that desirable values are achievable with suitable combinations of two parameters, i.e. the thickness of the inner layer and the percentage blow of the foam. For instance, where the thickness of the inner layer is 54 creased, this has an undesirable effect on the capacitance and, to counteract this, a higher percentage of air space needs to be provided in the outer cellular layer. The situation is, however, that the inner layer is located at the position of greatest field intensity and is sufficient to provide the required dielectric properties in an air-core cable while still being sufficiently thin to enable the cellular outer layer to be disposed as close to the conductor as possible and provide the required capacitance value.

The invention also includes a telecommunications cable having an air-core or a core filled with particulate material in which a plurality of insulated electrical conductors are provided, each of which comprises a conductor having insulation comprising an inner layer of solid non-cellular material and an outer layer of cellular polymeric material and wherein the nominal mutual capacitance between conductors is at a desired value and a dielectric breakdown value above an acceptable minimum is obtained between conductors with each conductor having an outside diameter across the insulation which is less than an electrical insulated conductor of the same conductor gauge which provides the same mutual capacitance and breakdown values and which is insulated with solid material only, the material being the same material of said inner layer.

In preferred constructions, the air space volume in the total volume of the cellular layer in the construction according to the invention is at least 20% whereby significant savings in materials may be obtained over materials required for conventionally insulated conductors in air-core cable.

One embodiment of the invention will now be described, by way of example, with reference to the accompanying drawings in which:—

Figure 1 is a cross-sectional view through a telecommunications cable; and

Figure 2 is a cross-sectional view of an insulated conductor incorporated in the cable.

In the embodiment now to be described, specific dimensions of conductor and insulation layers will not be referred to. Dimensions will be discussed at the end of the description for different gauges of conductor to enable comparisons to be made between the dielectric strength and capacity values of constructions of the embodiment and other insulated conductors not within the scope of this invention.

In the embodiment, a telecommunications cable 10 comprises a core having a plurality of pairs of insulated conductors 11. The core is wrapped in a composite wrap comprising an inner layer 12 of plastic tape, e.g. 3 mils thick, such as "Mylar" tape. The inner layer may comprise other materials such as paper or polyethylene or combinations of these materials. Around this is another layer 13 of aluminum tape, e.g. 8 mils thick which has been coated on both sides with polyethylene, followed by a medium density block polyethylene outer layer 14 of about 80 mils thickness.

"Mylar" is a Registered Trade Mark.

The core, commonly referred to as an air-core, has each insulated conductor 11 of each pair constructed in the manner shown in Figure 2. Each insulated conductor comprises a conductor 15 covered by an inner layer 16 of solid non-cellular insulating material which in line with this invention has a maximum thickness of 4 mils. This may be made from any suitable electrically insulating plastics material such as polypropylene or medium density polyethylene. An outer layer 17 enclosing the inner layer is cellular polypropylene which is preferably closed cell but may be of open cell structure. Alternatively, the inner layer and outer layer are both formed from high density polyethylene with the outer layer, of course, being cellular.

The insulated conductor is manufactured by passing conductor through a two stage extruder (not shown), the first stage providing the inner non-cellular insulating layer 13 and the second stage extruding the cellular layer. The cellular layer is formed by normal foam extrusion techniques.

It is found that while the cells expand directly after extrusion, expansion of the outer layer is outwardly from the inner layer and has no effect upon the inner layer which has just been extruded. Thus the inner layer is not stressed by its contact with the expanding outer layer and there is no likelihood of pinholes being formed in the inner layer because of stress build-up.

The thickness of each of the layers 13, 14 is predetermined primarily to give a desired nominal mutual capacitance value of 83 nanofarads/mile in the completed cable. Also to give the required dielectric properties, the inner layer is located at the position of greatest field intensity and its thickness is calculated to give satisfactory dielectric strength and thus to enable the outer cellular layer to lie as close as possible to the conductor so as not to detract from the required mutual capacitance.

Further, the material of the outer layer may be pigmented without detracting from the mutual capacitance properties unduly. While it is known that pigmentation may deleteriously affect the dielectric strength properties of an insulating layer, the inner layer is not pigmented and thus its dielectric strength is not so affected.

In the following, measurements were taken of the dielectric strengths of insulated conductor according to the above described embodiment for 22 AWG conductor. These appear in "Category A" of the following Table I.

For comparison, the test also includes measurements of dielectric strengths of insulated conductors made for grease filled cable in which the insulation has an inner cellular layer of polypropylene and an outer non-cellular layer of medium density polyethylene and as described in the above Canadian Patent No. 952,991.

In addition, and also for comparison, the test also includes measurements of dielectric strengths of insulated conductors in which the insulation is conventional and is non-cellular low density polyethylene throughout. These measurements appear as "Category C".

The test was conducted while submerging the insulated conductors concerned under water. This was done to simulate the worst possible conditions which insulated conductors in an air-core cable could experience, i.e. conditions in which the core is completely waterlogged. It should be stressed that these conditions should not normally be expected for air-core cable but are ones which could lead to premature dielectric breakdown.

A 1000 foot length of insulated conductor in Category 'A' and insulated on one production run ("1" in Table I) was tested in 30 foot sample lengths. Each sample length was immersed in water and a DC potential passed through it. The voltage was increased at a substantially uniform rate until dielectric breakdown occurred. The maximum and minimum dielectric breakdown values (Kv), recorded for all of the 30 foot sample lengths, are recorded in Table I together with the average breakdown figure. The above test procedure was then repeated for another 1000 foot length of conductor in Category 'A' which had been insulated on a different production run ("2" in Table I) and the results similarly recorded.

The test procedure was then performed for 30 foot sample lengths of two twisted together insulated conductors, in water in which conductor "1" was twisted with conductor "2". Results are given under column 3.

The whole of the above procedure was then repeated for two 1000 foot lengths of insulated conductor made under Category 'B' and dielectric breakdown values given under columns 4, 5 and 6.

Under Category 'C', tests were made and the breakdown values given under columns 7 and 8. No test was performed under Category 'C' for the insulated conductors twisted together.

**Table I**

| | | *Category A* | | | *Category B* | | | *Category C* | |
|---|---|---|---|---|---|---|---|---|---|
| | | *1* | *2* | *3* | *4* | *5* | *6* | *7* | *8* |
| D.C. Voltage Dielectric Breakdown (Kv) | Average | 15.2 | 15.1 | 29.4 | 10.5 | 15.3 | 17.5 | 36 | 48 |
| | Minimum | 11.5 | 11.0 | 22.0 | 8.5 | 4.0 | 8.0 | 12 | 27 |
| | Maximum | 17.0 | 16.5 | 32.5 | 13.0 | 22.0 | 19.0 | 46 | 60 |
| Outside Diameter of Insulation (mils) | | 43.3 | 42.7 | — | 48.0 | 48.0 | — | 45.5 | 44.8 |
| Thickness of Cellular Layer (mils) | | 6.7 | 6.4 | — | 8.7 | 8.3 | — | — | — |
| Thickness of Non-cellular Layer (mils) | | 2.3 | 2.3 | — | 2.6 | 3.0 | — | 10.1 | 9.7 |
| % Blow | | 26 | 27 | — | 35 | 35 | — | — | — |

It should be made clear at this stage that the insulated conductors in Category 'B' were designed for grease filled cable. The desired mutual capacitance of 83 nanofarads/mile would not be achieved between conductors of this construction for air-core cable. However, in contrast, conductors in both of Categories 'A' and 'C' have a nominal mutual capacitance of 83 nanofarads/mile for air-core cable.

As may be seen from the above Table I, the dielectric breakdown values for conventionally insulated conductor (Category 'C') were consistently very high with very high average breakdown values of 36Kv and 48Kv. While the breakdown values for insulated conductors according to the embodiment described above were much lower than those of Category C, these values for the embodiment are extremely satisfactory (Category A) and are significantly above one requirement for commercially acceptable air-core cable. This requirement is for a length of insulated conductor to withstand a voltage of 8Kv DC between conductors for a period of 1 to 3 seconds without dielectric breakdown. Column 3 shows these breakdown values between conductors for Category 'A'. The minimum is 22Kv DC which is well above the requirement of 8Kv DC by at least some authorities. Column 3 results are interesting in that they indicate values approximately twice those obtained for the single wires in columns 1 and 2. This doubling in values between conductors illustrate not only that current needed to pass through two layers of insulation on both conductors (as distinct from two layers on one conductor in columns 1 and 2), but also that the inner insulation layers of solid material were adding their dielectric strength characteristics without these being degraded by flaws in the layers. This illustrates that there were no physical stresses causing flaws in the inner layers and no impurities, e.g. colour pigments in the layers, both of which would tend to deleteriously affect the results obtained. As a means of comparison with Category 'B', it may be seen that the dielectric breakdown values in column 6 are certainly not of the order of double those obtained for single conductors in columns 3 and 4. In fact, they are not significantly different from columns 3 and 4. It is believed, that the lack of the doubling value effect in column 6 can be blamed upon physical stresses imposed by the inner cellular layers, during extrusion upon the outer solid layers of Category 'B' construction, whereby flaws and pinholes are formed, and upon the use of colour pigmentation in these outer layers.

Hence, the dielectric strength between conductors for the Category 'A' construction is significantly higher than for the Category 'B' construction. It should be remembered that Category 'B' insulated conductor was made for grease filled cable and would have a dielectric strength suitable for this purpose. However, if insulated conductor under Category 'B' were designed for air-core cable while providing the desired nominal 83 nanofarads/mile mutual capacitance and having a diameter less than that of Category 'C', then this would lead to a dielectric strength below that established by the conductors in Category 'A'.

The results obtained for the construction of the invention were, as already stressed, well above the acceptable levels specified, and because of the use of an outer layer of cellular material with a blow of 35% or less (i.e. 35% of air space in the total volume of the outer layer), there was a significant saving in material compared to the construction of Category 'C', with attendant cost saving. In addition, these commercially acceptable results were obtained with outside diameters of insulation in the Category 'A' construction which were at least 1.5 mils less than the outside diameters of the Category 'C' construction. Hence, it follows that a resultant air-core cable made with insulated conductors according to the invention will have an outside diameter less than one made using conductors of conventional Category 'C' while being more economic and providing well above the commercially acceptable levels of dielectric breakdown between conductors.

The recorded values in Table I indicate that constructions according to the invention are a desirable replacement for constructions using a single layer of solid material. Clearly, in most practical constructions, the inner layer should have a maximum thickness of 4 mils to enable the cellular layer to lie as close as possible to the conductor to obtain the required capacitance level.

In constructions according to the invention, the amount of air space in the total volume of the outer layer is a parameter in deciding the capacitance whereas the amount of polymeric material is a parameter for the dielectric strength. While the air space may be as much as 50% or more of this volume, to obtain a desirable balance between desired capacitance and desired dielectric strength while enabling a reduction in outside diameter of the insulation below that for insulated conductor in Category 'C', the air space may need to be at a maximum of 40% and a minimum of 10% for the use of an inner non-cellular layer of maximum thickness of 4 mils.

In addition, conductors according to this invention and as described in the embodiment, may be used for cores filled with particulate material, as acceptable dielectric strengths are obtainable.

The invention is applicable to all conductor gauges which are useful for telecommunications cable and, for all these gauges, that is 19, 22, 24, 26, and 28 at least, acceptable dielectric strengths are obtainable with maximum thicknesses of 4 mils for the non-cellular inner layer. The following Table II compares the constructions of Categories A, B and C in conductor gauges 19, 22 and 24. Table II shows the savings obtained in insulation material in both Categories 'A' and 'B' over Category 'C'. While the savings in this table for Categories 'A' and 'B' are comparable, it should be remembered from the above discussion that the insulated conductors of the invention (Category 'A') provide dielectric strengths for air-core cable which are more acceptable than conductors according to Category 'B'.

**Table II**

| SWG | Construction | Thickness non-cellular layer (mils) | Outside diameter of insulation (mils) | Wt/ft (MG) | Air space % | Wt saving over Category 'C' | % Diameter reduction |
|---|---|---|---|---|---|---|---|
| 19 | Category A | 3 | 56.7 | 220 | 25 | 38 | 6.9 |
| | | 4 | 57.3 | 234 | 25 | 34 | 5.9 |
| | | 3 | 55.4 | 186 | 35 | 47 | 9.0 |
| | Category B | 3 | 57.0 | 263 | 20.2 | 25 | 6.4 |
| | | 3 | 56.0 | 242 | 26.6 | 31 | 8.0 |
| | Category C | — | 60.9 | 337 | — | — | — |
| 22 | Category A | 3 | 41.3 | 125 | 25 | 33 | 6.1 |
| | | 4 | 41.8 | 134 | 25 | 29 | 5.0 |
| | | 3 | 41.8 | 134 | 20 | 29 | 5.0 |
| | Category B | 3 | 42.0 | 151 | 14.5 | 20 | 4.5 |
| | | 3 | 40.5 | 125 | 28.2 | 33 | 8.0 |
| | Category C | — | 44.0 | 188 | — | — | — |
| 24 | Category A | 3 | 33.2 | 84 | 25 | 30 | 5.1 |
| | | 4 | 33.7 | 92 | 25 | 23 | 3.7 |
| | | 3 | 33.5 | 89 | 20 | 26 | 4.3 |
| | Category B | 3 | 33.2 | 89 | 19.5 | 26 | 5.1 |
| | Category C | — | 35.0 | 120 | — | — | — |

**Claims**

1. An insulated electrical conductor for telecommunications cable comprising a telecommunications conductor and an insulation comprising an inner layer and an outer layer of electrically insulating material, the inner layer of solid non-cellular construction and the outer layer of cellular polymeric material, and wherein the nominal mutual capacitance between the conductor and an identically insulated conductor in a pair is at a desired value and a dielectric breakdown value above an acceptable minimum is obtained between the conductor and an identically insulated conductor while having an outside diameter across the insulation which is less than an insulated electrical conductor of the same gauge which provides the same mutual capacitance and which is insulated with solid non-cellular material only, the material being the same material as said inner layer.

2. A conductor according to claim 1 wherein the inner layer has a maximum thickness of 4 mils.

3. A conductor according to claim 1 wherein the outer layer has closed cells.

4. A conductor according to claim 1 wherein the cells provide an air space which is at least 10% of the total volume of the outer layer.

5. An electrically insulated conductor according to claim 4 wherein the air space in the outer layer is between 10% and 40%.

6. A telecommunications cable having an air-core or a core filled with particulate material in which a plurality of insulated electrical conductors are provided, each of which comprises a conductor having insulation comprising an inner layer of solid non-cellular material and an outer layer of cellular polymeric material and wherein the nominal mutual capacitance between conductors is at a desired value and a dielectric breakdown value of above an acceptable minimum is obtained between conductors with each conductor having an outside diameter across the insulation which is less than an electrical insulated conductor of the same conductor gauge which provides the same mutual capacitance and which is insulated with solid material only, the material being the same material of said inner layer.

Printed for Her Majesty's Stationery Office by the Courier Press, Leamington Spa, 1982. Published by the Patent Office, 25 Southampton Buildings, London, WC2A 1AY, from which copies may be obtained.

Dec. 12, 1961 L. I. GORMAN ET AL 3,013,109
ELECTRIC CABLE
Filed March 16, 1961

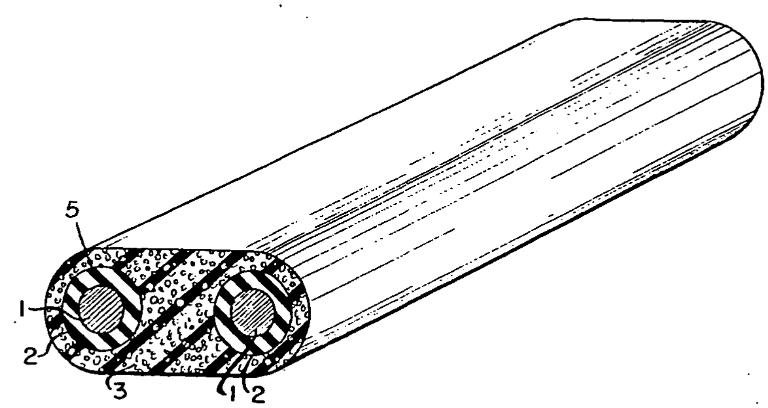


Fig: 1

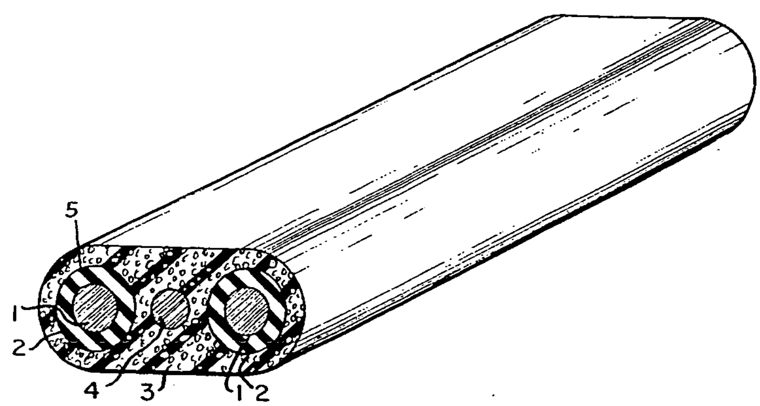


Fig: 2

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# United States Patent Office

3,013,109
Patented Dec. 12, 1961



3,013,109
ELECTRIC CABLE

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Filed Mar. 16, 1961, Ser. No. 96,638
5 Claims. (Cl. 174—113)

Our invention relates to electric cables and particularly to protective-sheathed power cables having a novel type of sheathing material.

This application is a continuation-in-part of our copending application, Serial #28,978, filed May 13, 1960, now abandoned.

In the manufacture of certain commonly used types of electric cable, for example, non-metallic sheathed cable for building wiring, it has long been commercial practice to apply two different types of material covering, one for insulation and other for protective sheathing. The insulation is applied directly over the cable conductors with the possible interposition of a thin separator or semiconducting tape, and has as its function the electrical isolation of the conductor. The function of electrical isolation has determined that the properties of materials suitable for insulation be, among others, high insulation resistance, and, for high voltage and communication cables, low specific inductive capacitance.

The protective sheath, as distinguished from the insulation, is applied over one or more conductors which have previously been insulated, and its function, almost exclusively physical rather than electrical, is to protect the insulated conductors from the external environment. For this reason the characteristics required of a sheathing material have traditionally been abrasion resistance, high strength, and toughness. Non-metallic protective sheaths have commonly been reinforced with fabric and have employed materials such as Neoprene which has poor electrical properties but outstanding toughness and strength.

It is an object of our invention to provide a rugged electric cable having low cost and low weight.

It is a further object of our invention to provide a cable, comparable in cost and ruggedness to cable having a braided or other tough fibrous sheath, but free from bituminous coating material.

It is a further object of our invention to provide a cable that is readily bendable, particularly in the plane of the conductors.

Other objects will become apparent from a study of the details of our invention hereinafter described.

Returning to consideration of materials suitable for electrical insulation, it is known that air has very high insulation resistance and low SIC at voltage stresses insufficient to cause ionization. For this reason expanded cellular plastics have found employment as insulation, particularly for low-voltage, high-frequency cables such as TV lead-in cables where a low SIC is the most important desideratum. Where such cables have required mechanical protection they have been surrounded by protective sheaths of the usual tough, dense compositions mentioned above.

Methods of appying cellular plastic insulation are known. These methods involve including in the plastic material a solid blowing agent which will decompose at some predetermined temperature to generate bubbles of gas within the plastic mass. If the decomposition temperature is reached while the plastic is confined under high pressure the released gas will remain compressed until the pressure is lowered, at which time, if the plastic is still hot and soft enough, expansion of the gas will take place to form a cellular structure of bubbles within the plastic. Known blowing agents for the release of gas in



expandable plastic material include p,p'-oxybis (benzenesulfonyl hydrazide), N,N'-dimethyl-N,N'-dinitrosoterephthalamide, and azocarbonamide.

Among the types of electric cable recognized by the National Electrical Code are type NM and type NMC used for wiring buildings for service at 110 volts in locations where local codes do not require that the wiring be confined in conduits. The cable may be secured by staples and, during its installation, fished through walls. In this process of installation, the cable will scrape against the rough edges of lumber and against other harsh surfaces that demand a rugged cable covering. The most widely used present construction of type NM cable employs parallel conductors, polyvinyl chloride insulation, a paper tape wrap over the insulated conductors, fibrous braid over the tape wrap, asphalt saturant, and an over-all light-colored paint finish. In an alternative construction a solid polyvinyl chloride jacket is substituted for all the cable elements external to the polyvinyl chloride insulation, with a fiberglass serving over the insulated conductors to provide slippage. However the cost of polyvinyl chloride is relatively high so that the braid and asphalt construction still dominates the market for type NM cable.

For many years it has been standard practice to subject types NM and NMC cable to a joist test. In this test eight boards of lumber, each of 2-inch nominal thickness, are spaced 16 inches apart in a frame. Holes ⅝-inch in diameter are drilled in each of the boards with the holes in alternate boards offset a distance of 2 inches. One end of a length of the cable to be tested is threaded through the holes and then the entire length is pulled through by means of tension of the leading end. Since the holes are alternately off center the cable is dragged in a zigzag path and subjected to severe scraping at the edge of each of the eight holes. A fibrous braided or solid polyvinyl chloride sheath has heretofore been deemed necessary to adequately protect the cable under such conditions. However, when the braided, asphalt-saturated construction of type NM cable is pulled through the joist testing equipment described above there is a tendency for the paint and/or asphalt coating to scrape off at the sharp edges of the holes, with some consequent impairment of its protective qualities.

Known cables for NM service have required an intermediate layer between the insulation and the sheath to provide adequate slippage. In the case of saturated braid cables this layer has usually been paper, and in the case of solid plastic sheathed cables it has consisted of a glass fiber serving or a film of Mylar polyester manufactured by E. I. du Pont de Nemours & Co., Inc. The use of oily or powdery lubricants has not been adequate to provide permanent slippage between the insulation and the sheath of conventional cables.

We have made the surprising discovery that expanded cellular organic material, similar to the material known to the prior cable art only for high frequency insulation, can be advantageously used to form the protective sheath of electric cables.

The cables made in accordance with our invention were unexpectedly found to be bendable without distortion and after being deliberately bent at a selected angle to maintain their bent shape indefinitely. It was possible not only to make acceptable bends in the cables across the plane of the conductors but to make flat (or edgewise) bends within the plane of the conductors. It will be readily recognized that such bendability has a particular merit in cables intended for permanent installation within the walls and around the joists and corners of frame buildings. The unexpected bendability of cables made to the teachings of this invention may be due in part to the relatively low frictional resistance between the dense semi-

rigid polyvinyl chloride insulation and the expanded cellular jacket, and indeed it has been discovered that the insulated conductors do, in fact, slip within the jacket when the cables of this invention are subjected to bending. The compressibility of the gas pockets in the jacket is also a probably contributing source of the bendability of these cables permitting said jackets to contract on the concave surface of the bends. A cable construction made to the teachings of our invention will comprise a plurality of metallic conductors each covered with dense solid insulation, and an outer protective sheath over-all, the sheath characteristically being composed essentially of a tough, flexible resinous plastic material such as polyvinyl chloride in expanded cellular form. The sheath is distinct from the insulation and is slippable or slidable thereon with the result that the cable can be readily bent without distortion. Thus we have made a flat cable for type NM and NMC service having parallel conductors insulated with extruded solid polyvinyl chloride, laid parallel, sheathed with a protective sheath of expanded cellular polyvinyl chloride and readily bendable in the plane of the conductors without warping. Preferably, the density of the expanded cellular plastic sheath material is in the range from 50% to 75% of that the same plastic material in dense non-cellular form. We have also provided cables of the above type with dry, pulverulent lubricant between the sheath and the insulation.

Two preferred embodiments of our invention are illustrated in the accompanying drawing, wherein:

FIG. 1 is a sectionalized perspective view of a 2-conductor cable made to the teachings of this invention.

FIG. 2 is a sectionalized perspective view of a 2-conductor cable with ground return made to the teachings of this invention.

The conductors 1 shown in the drawings are solid wires of copper or aluminum, but each of the conductors 1 may if desired be composed of a plurality of relatively small wires stranded or twisted together. Each of the conductors 1 is covered with a layer of insulation 2 which is preferably of extruded semirigid polyvinyl chloride, but may be polyethylene, rubber or any other material suitable for electrical insulation, and may be applied by wrapping, by dipping or by other processes known to the cable insulating arts, instead of by extrusion.

We prefer to lubricate the insulation 2 with a coating 5 of a dry pulverulent dust such as ground silica, talc or mica powder. This may be accomplished by merely passing the insulated conductor through a box of the lubricating powder.

As shown the conductors are laid parallel and are covered with a protective sheath 3 of expanded cellular organic material which also fills the space between the insulations 2. This expanded cellular sheath may be applied to the insulated conductor by extruding it thereover similarly to the application of expanded cellular insulation to twin conductor parallel high frequency cable. For example, the two conductors 1 with their respective layers of insulation 2 may be guided through an extrusion apparatus by which the polyvinyl chloride sheath composition containing a blowing agent is extruded thereabout. As the insulated conductors surrounded by the hot sheath composition emerge from the extruder, the sheath composition is expanded by the blowing agent into its final cellular form.

By virtue of the expansion of the polyvinyl chloride into cellular form, a sheath of desired thickness over the insulated conductors and filling the space between them can be formed with a much less weight of polyvinyl chloride than if it were solid. Hence, the cost of the sheath is reduced to a value commensurate with asphalt-saturated fibrous braid construction. Yet the expanded cellular sheath provides substantially as effective mechanical protection for the cable as a solid polyvinyl chloride sheath, and even better protection than the braided asphalt-impregnated sheath.



As indicated above, the expanded cellular polyvinyl chloride (or other tough resinous plastic sheath material) has a density less than 75% of that of the same material in its dense non-cellular form, for at higher densities the economic advantages of the invention are largely lost. On the other hand, the density of the expanded cellular plastic sheath should not be less than about 50% of that of the same plastic material in dense non-cellular form, for then it becomes too foamy and fragile and loses the toughness, compression resistance and other physical properties which enable it to provide the original mechanical protection to the insulated conductors. Generally the density of the cellular expanded sheath material should be about 70% of that of the material in dense unexpanded form.

An uninsulated grounding wire 4 may be laid between the two conductors as shown in FIG. 2 in which case the space between the conductors will preferably be increased to accommodate the grounding wire.

Cables were made according to the present invention embodying the following specific constructions:

*Example I*

Conductors (2)—14 AWG hard-drawn copper
Insulation—$\frac{2}{64}$ inch wall semirigid polyvinyl chloride dusted with ground silica [1]
Cabling—2 conductors parallel at 0.135 inch spacing
Protective sheath—expanded cellular polyvinyl chloride
Outside dimensions—.241 x .437 inch
Gas content of protective sheath—29%

*Example II*

Conductors (2)—14 AWG soft-drawn copper conductor
Conductor (grounding)—16 AWG soft drawn copper
Insulation—$\frac{2}{64}$ inch wall semirigid polyvinyl chloride dusted with ground silica [1]
Cabling—2 conductors parallel at 0.155 inch spacing, uninsulated grounding conductor centered between the two insulated conductors
Protective sheath—expanded cellular polyvinyl chloride
Outside dimension—.228 x .446 inch
Gas content of protective sheath—27%

[1] Neo Novacite supplied by Malvern Minerals Co.

The joist pull test of the character described above was made after subjecting the cables of Examples I and II to a —20° C. temperature for 18 hours. There were no noticeable effects on the cables after the joist pulling.

Particular reference has been made herein to polyvinyl chloride insulation and expanded cellular sheath. It is understood that other resinous vinyl compositions are equally satisfactory, such as compositions employing polyvinyl acetate; and, in fact, the term "polyvinyl chloride" as used herein includes all the usual insulating and other compositions based on polyvinyl chloride and its copolymers with vinyl acetate which are employed for insulation and sheathing purposes in the electric cable industry.

We claim:

1. A sheathed electric power cable comprising a plurality of coplanar parallel metallic conductors, a solid layer of semirigid polyvinyl chloride insulation over each of said conductors, an outer continuous protective sheath completely surrounding said insulated conductors, said sheath consisting of polyvinyl chloride in expanded cellular form, said sheath being distinct from said insulation and slidable thereon whereby said cable can be readily bent in the plane of said conductors without warping.

2. A sheathed electric power cable comprising a plurality of coplanar parallel metallic conductors, a solid layer of semirigid polyvinyl chloride insulation over each of at least two of said conductors, an outer continuous protective sheath completely surrounding said conductors and said insulation, said sheath consisting of polyvinyl

chloride in expanded cellular form, said sheath being distinct from said insulation and slidable thereon whereby said cable can be readily bent in the plane of said conductors without warping.

3. A sheathed electric power cable comprising a plurality of coplanar parallel metallic conductors, a solid layer of dense electrical insulation over each of at least two of said conductors, an outer continuous protective sheath completely surrounding said conductors and said insulation, said sheath consisting of polyvinyl chloride in expanded cellular form having a density in the range from 50% to 75% of that of the same polyvinyl chloride in dense non-cellular form, said sheath being distinct from said insulation and slidable thereon whereby said cable can be readily bent in the plane of said conductors without warping.

4. A sheathed electric power cable comprising a plurality of coplanar parallel metallic conductors, a solid layer of semirigid polyvinyl chloride insulation over at least two of said conductors, a dry pulverulent lubricant coating said insulation, an outer continuous protective sheath completely surrounding said conductors and said insulation, said sheath consisting of polyvinyl chloride in expanded cellular form, said sheath being distinct from said insulation and slidable thereon whereby said cable can be readily bent in the plane of said conductors without warping.

5. A sheathed electric power cable comprising a plurality of coplanar parallel metallic conductors, a solid layer of dense electrical insulation over each of said conductors, an outer continuous protective sheath completely surrounding said conductors and said insulation, said sheath consisting of polyvinyl chloride in expanded cellular form having a density in the range from 50% to 75% of that of the same polyvinyl chloride in dense non-cellular form, said sheath being distinct from said insulation and slidable thereon, whereby said cable can be readily bent in the plane of said conductors without warping.

References Cited in the file of this patent

UNITED STATES PATENTS

| | | |
|---|---|---|
| 2,186,793 | Wodtke | Jan. 9, 1940 |
| 2,718,544 | Shepp | Sept. 20, 1955 |
| 2,737,503 | Sprague et al. | Mar. 6, 1956 |
| 2,805,276 | Weitzel | Sept. 3, 1957 |

FOREIGN PATENTS

| | | |
|---|---|---|
| 742,760 | Great Britain | Jan. 4, 1956 |